US009883873B2

(12) **United States Patent**
Kulas et al.

(10) **Patent No.: US 9,883,873 B2**
(45) **Date of Patent: Feb. 6, 2018**

(54) **SURGICAL BURS WITH GEOMETRIES HAVING NON-DRIFTING AND SOFT TISSUE PROTECTIVE CHARACTERISTICS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 3 days.

(21) Appl. No.: **13/944,650**

(22) Filed: **Jul. 17, 2013**

(65) **Prior Publication Data**

US 2015/0025559 A1 Jan. 22, 2015

(51) **Int. Cl.**

A61B 17/16	(2006.01)
B23C 5/10	(2006.01)
A61C 3/02	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 17/1695*** (2013.01); ***A61B 17/1615*** (2013.01); ***B23C 5/1009*** (2013.01); *A61C 3/02* (2013.01); *B23C 2210/0407* (2013.01)

(58) **Field of Classification Search**

CPC . A61B 17/16; A61B 17/1695; A61B 17/1615; A61B 17/1642; A61B 17/1617; B23C 5/02; B23C 5/1009; A61C 1/084; A61C 1/082; A61C 1/085; A61C 1/186; A61C 3/02; A61C 5/40

USPC 606/79–80, 180, 102, 107, 187, 83; 408/109, 202, 227, 230, 147; 433/72, 75, 433/102, 134, 143, 144

See application file for complete search history.

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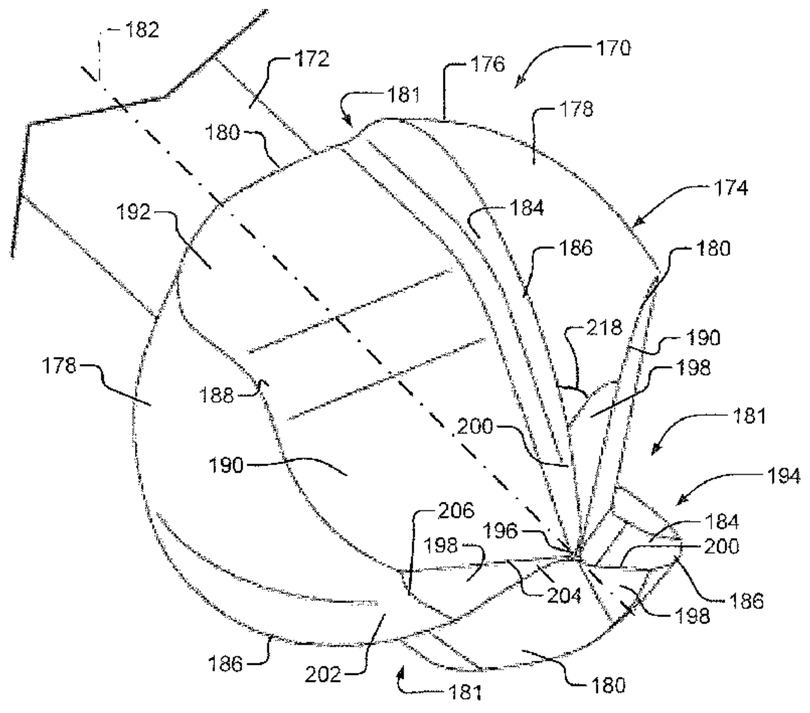
(57) **ABSTRACT**

A surgical bur includes a body and a drill point. The body includes flutes and lands. Each of the flutes includes a cutting edge, a rake face, and a clearance surface. Each of the lands is convex-shaped and disposed between a pair of the flutes. The drill point includes axial relief surfaces. Each of the axial relief surfaces has a planar area, is distinct from the lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the lands, and (iii) one of the clearance surfaces.

43 Claims, 8 Drawing Sheets



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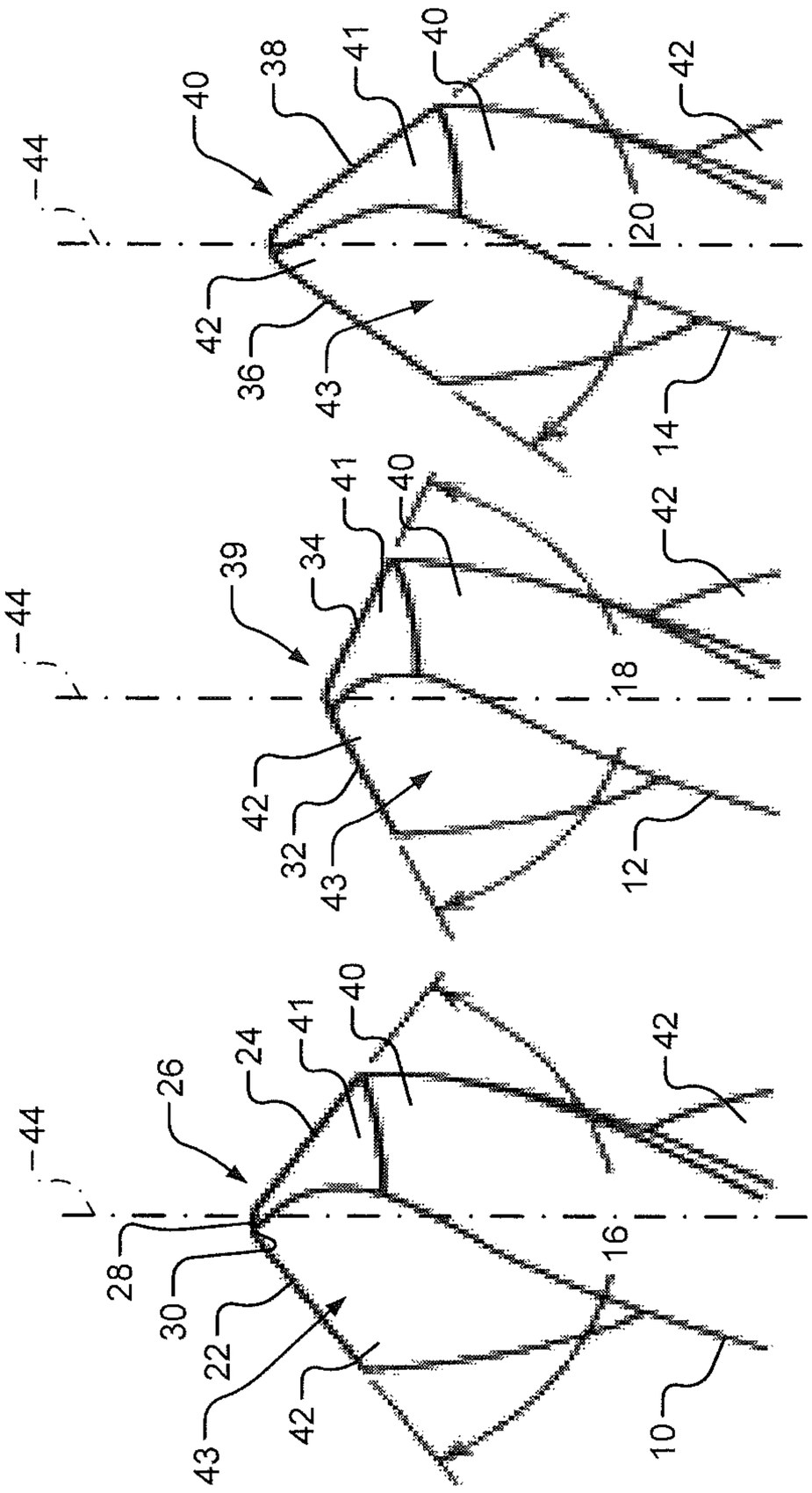

FIG. 1
Prior Art

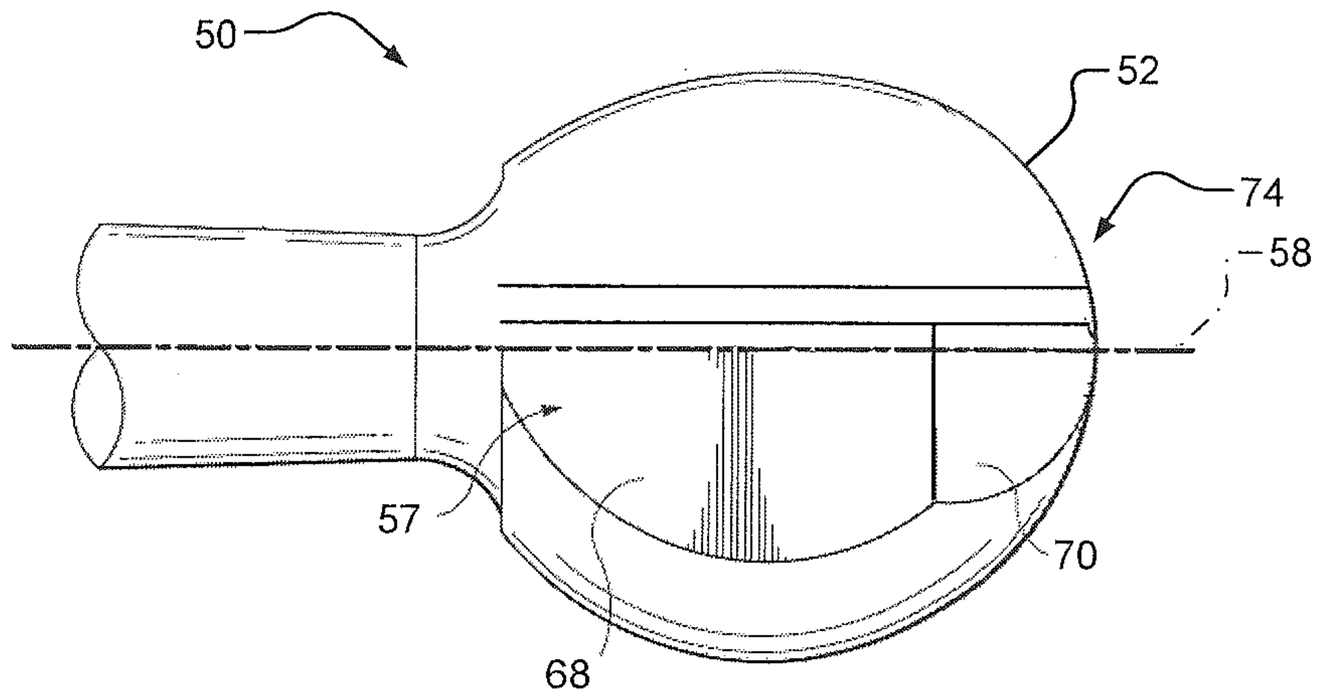

FIG. 2
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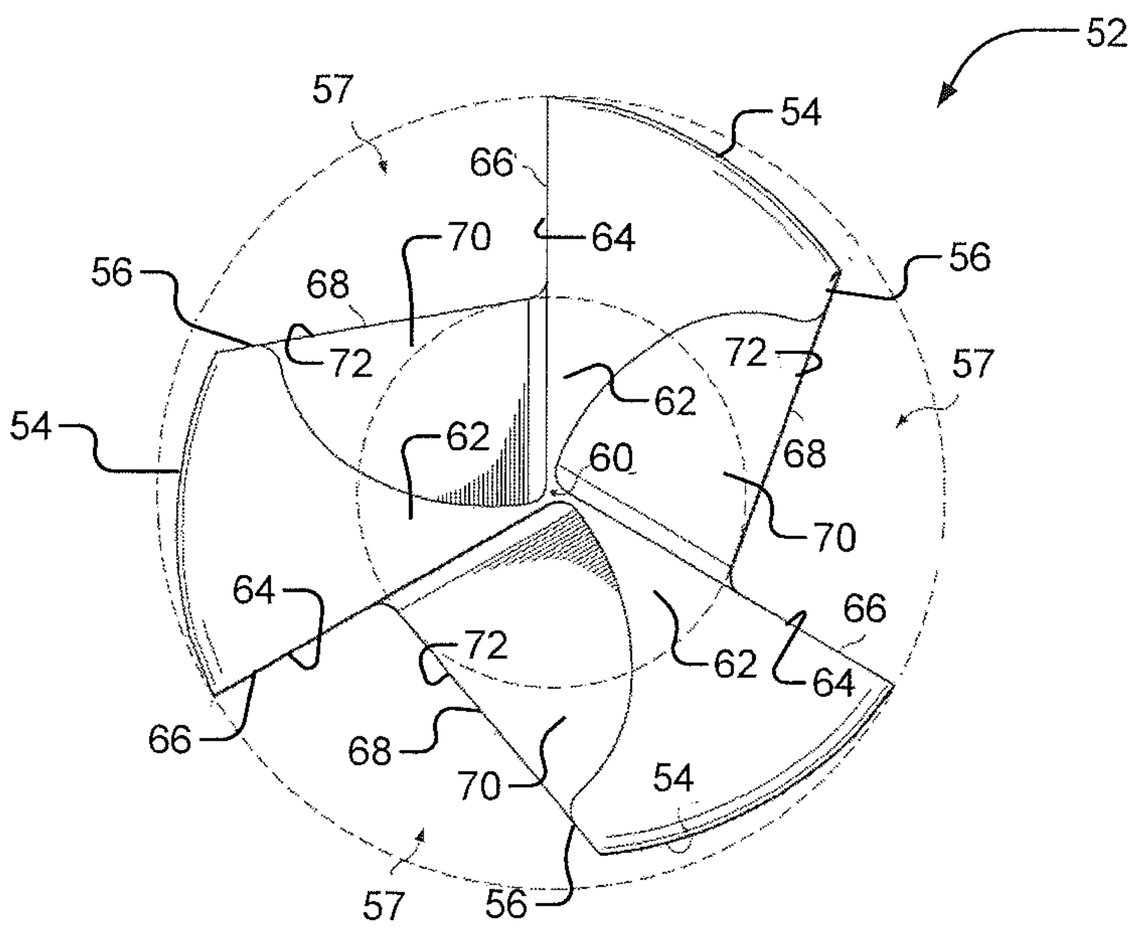

FIG. 3
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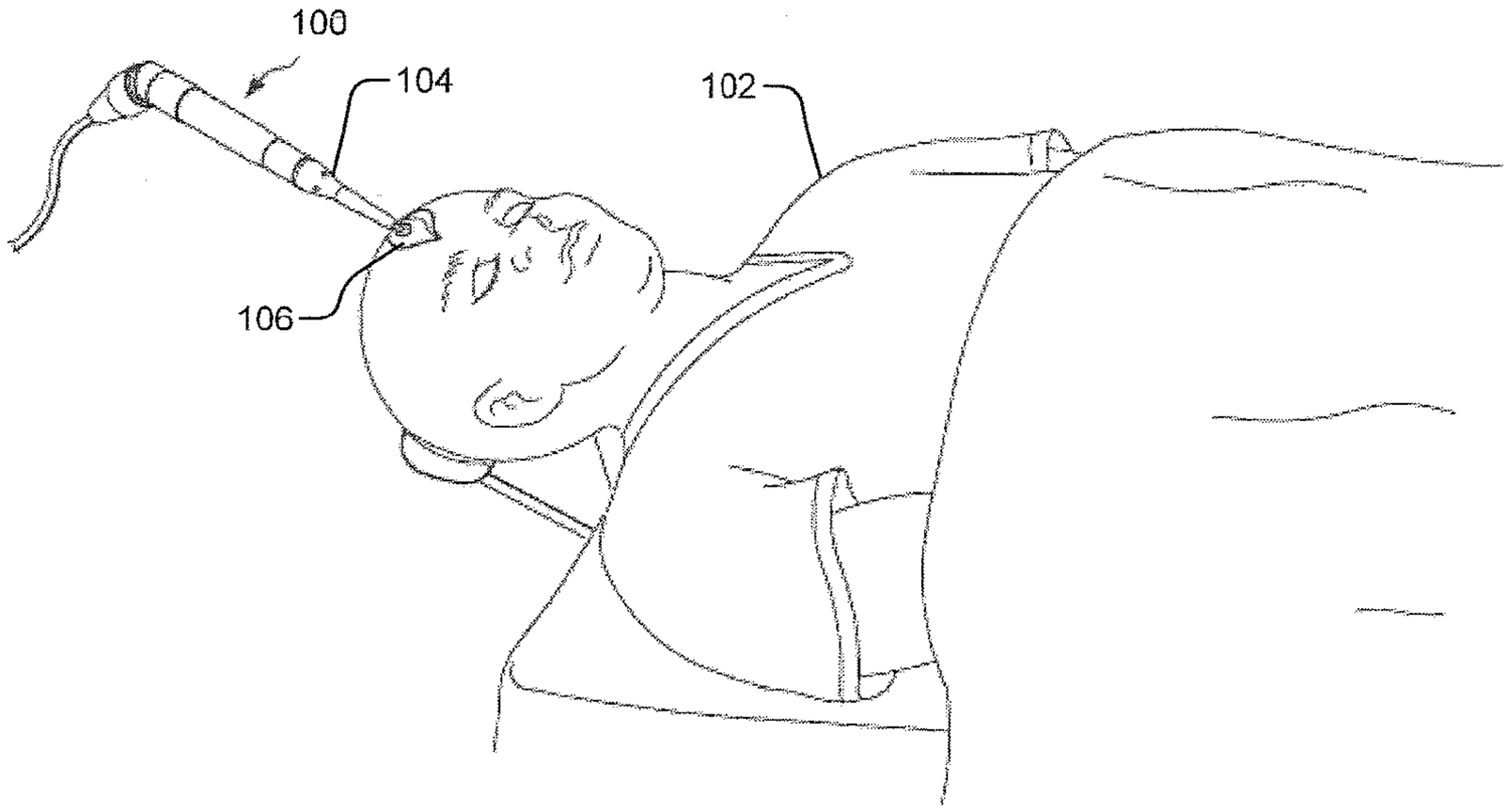

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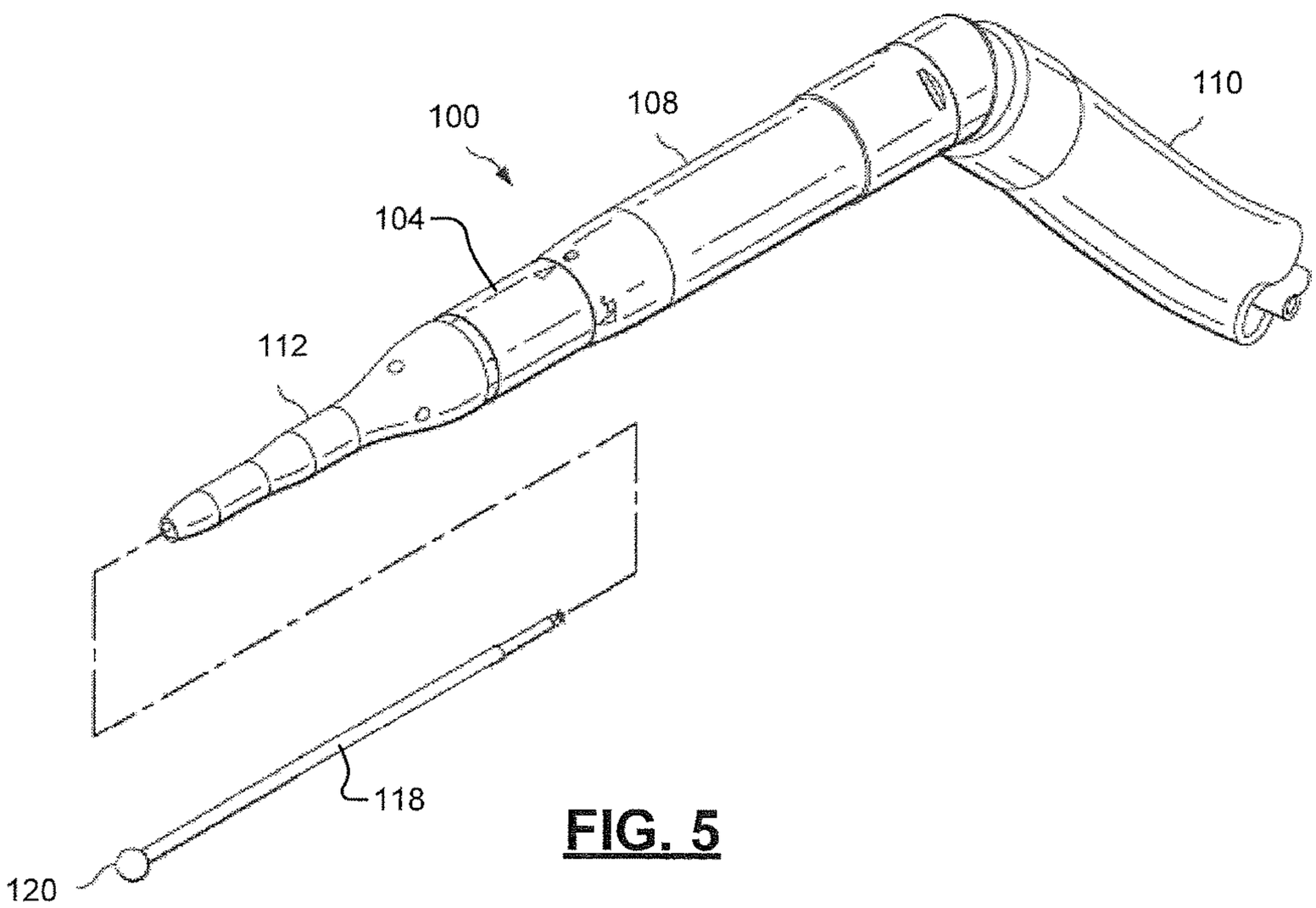

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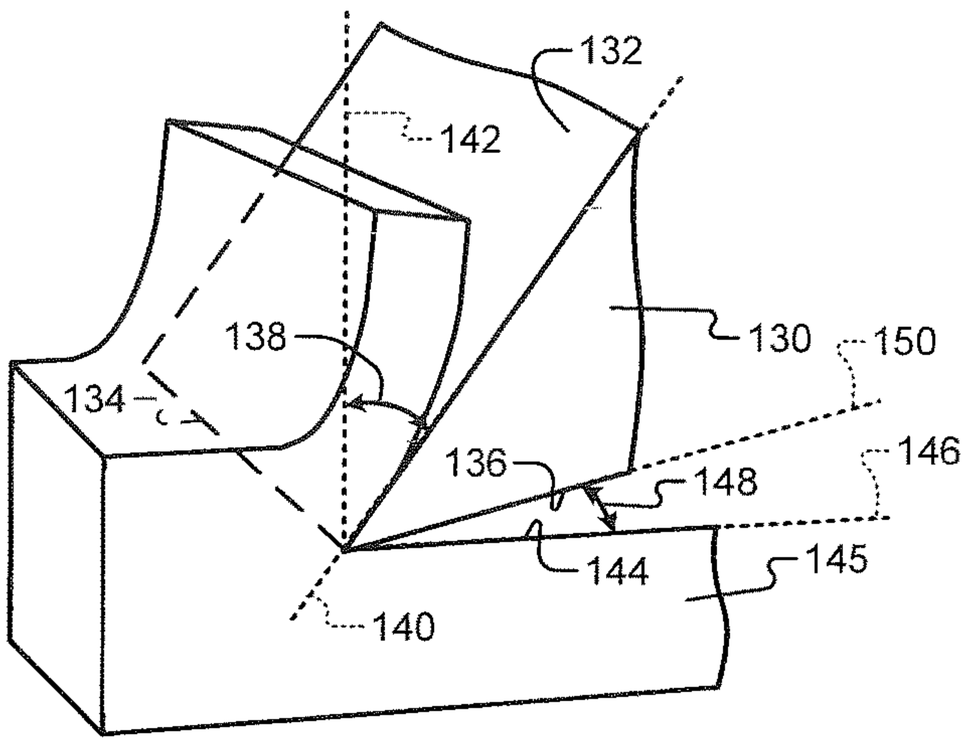
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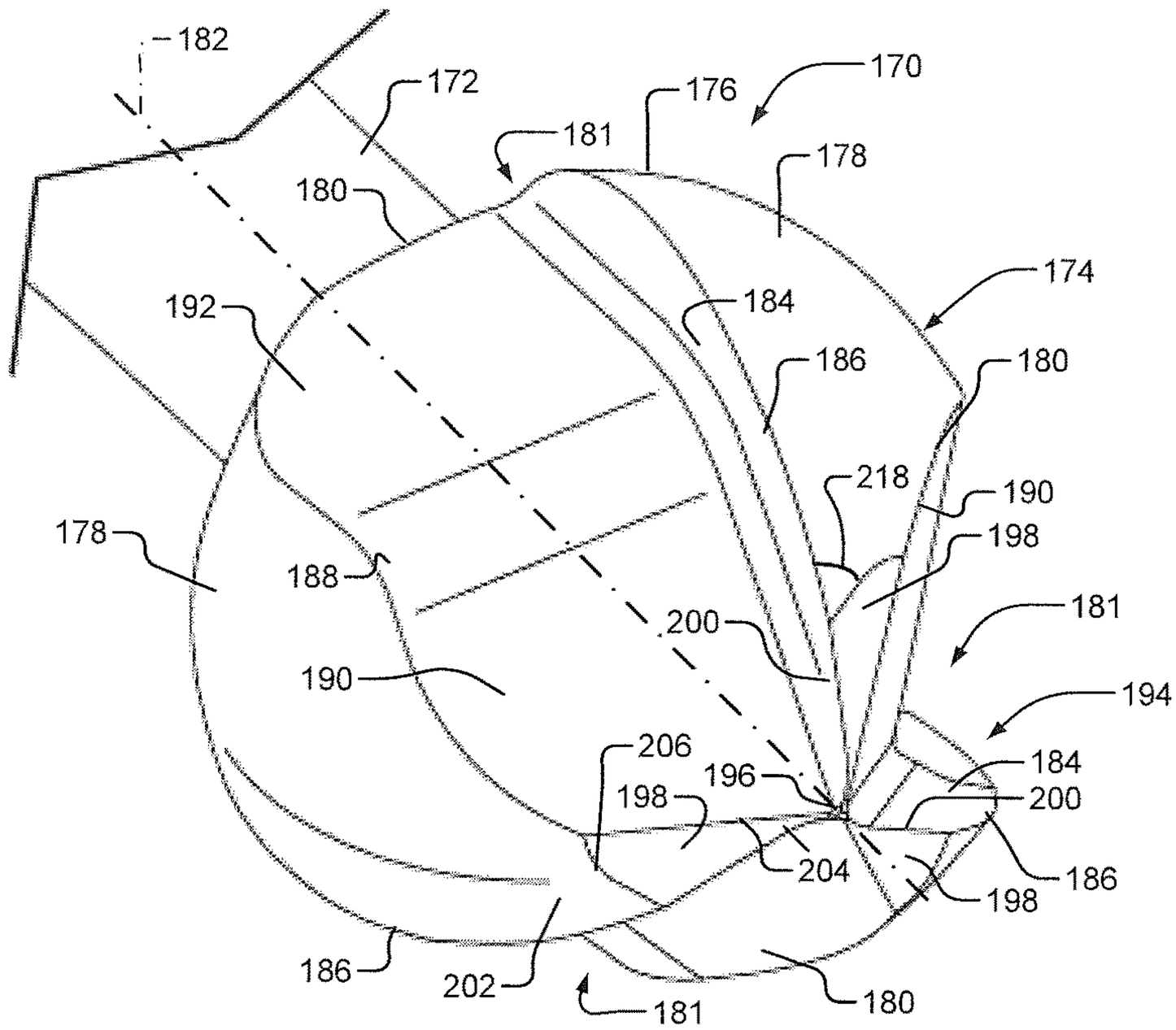
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FIG. 7

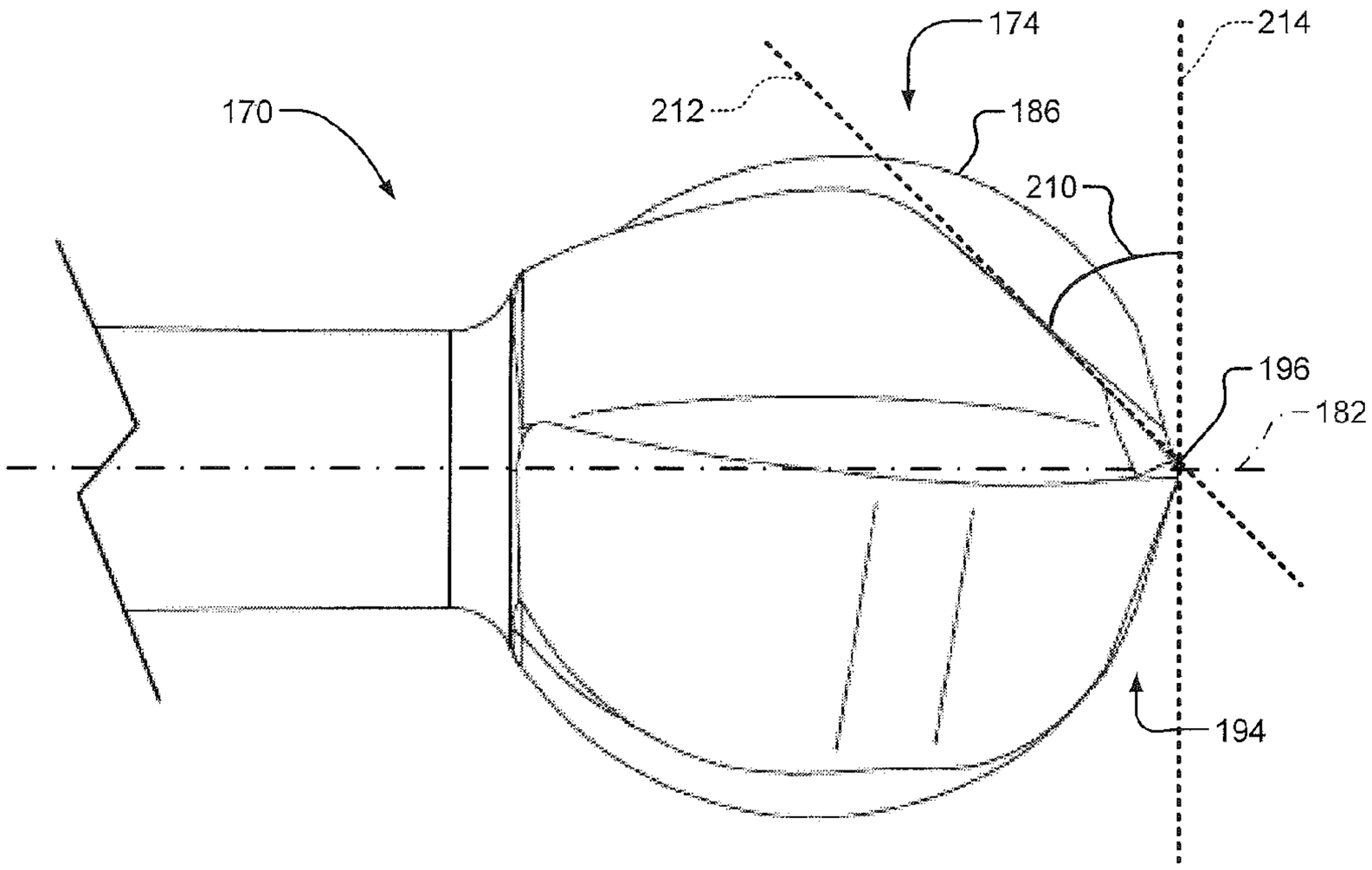
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FIG. 8

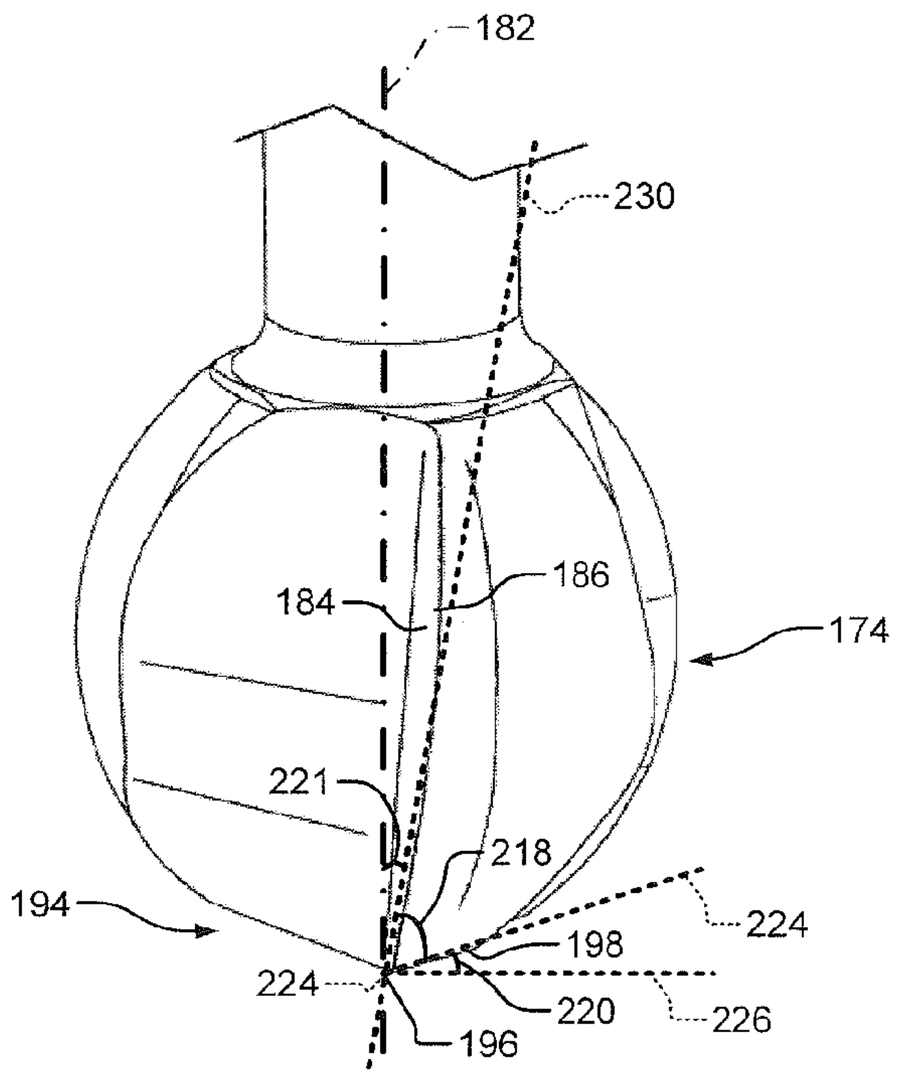
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FIG. 9

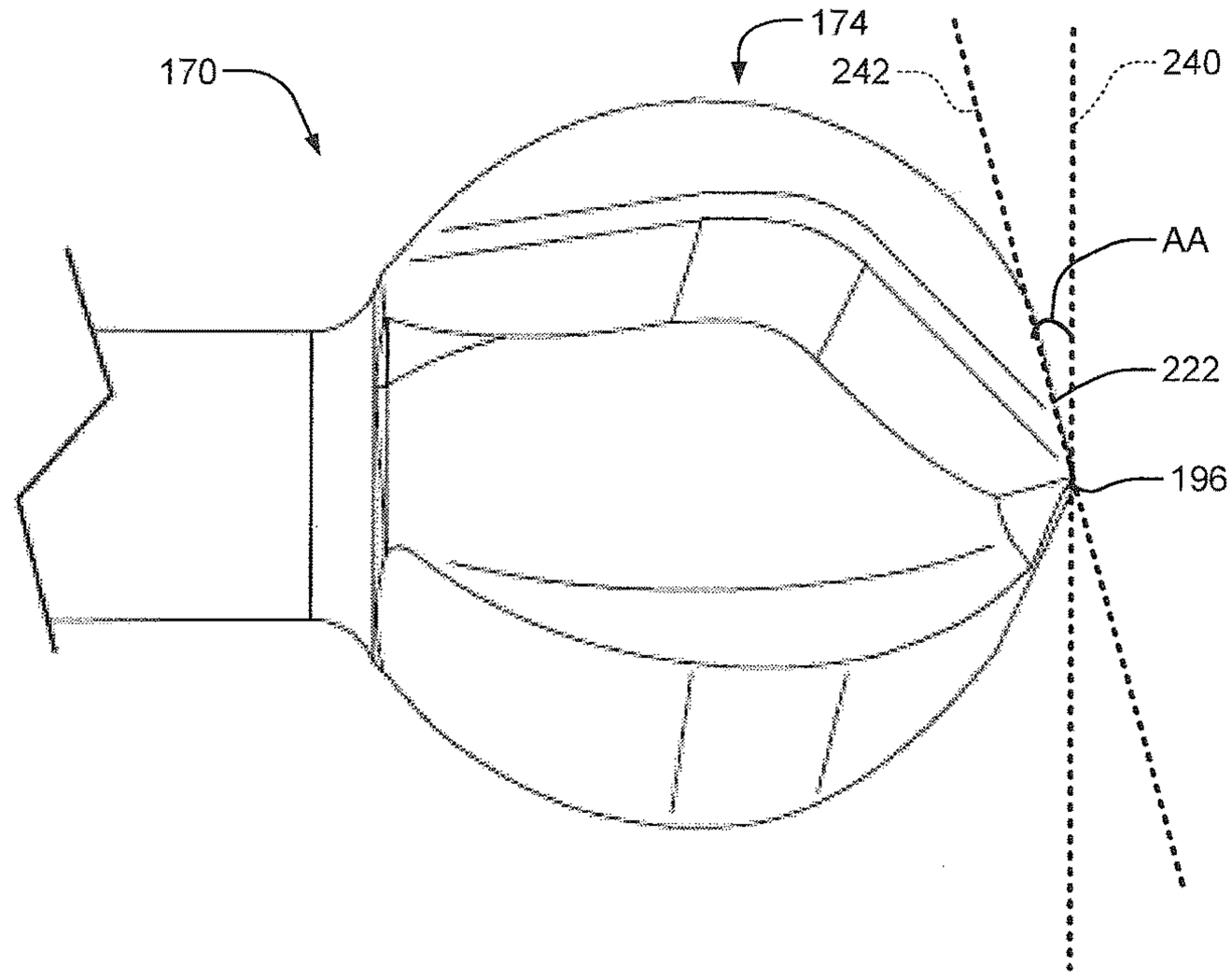

FIG. 10

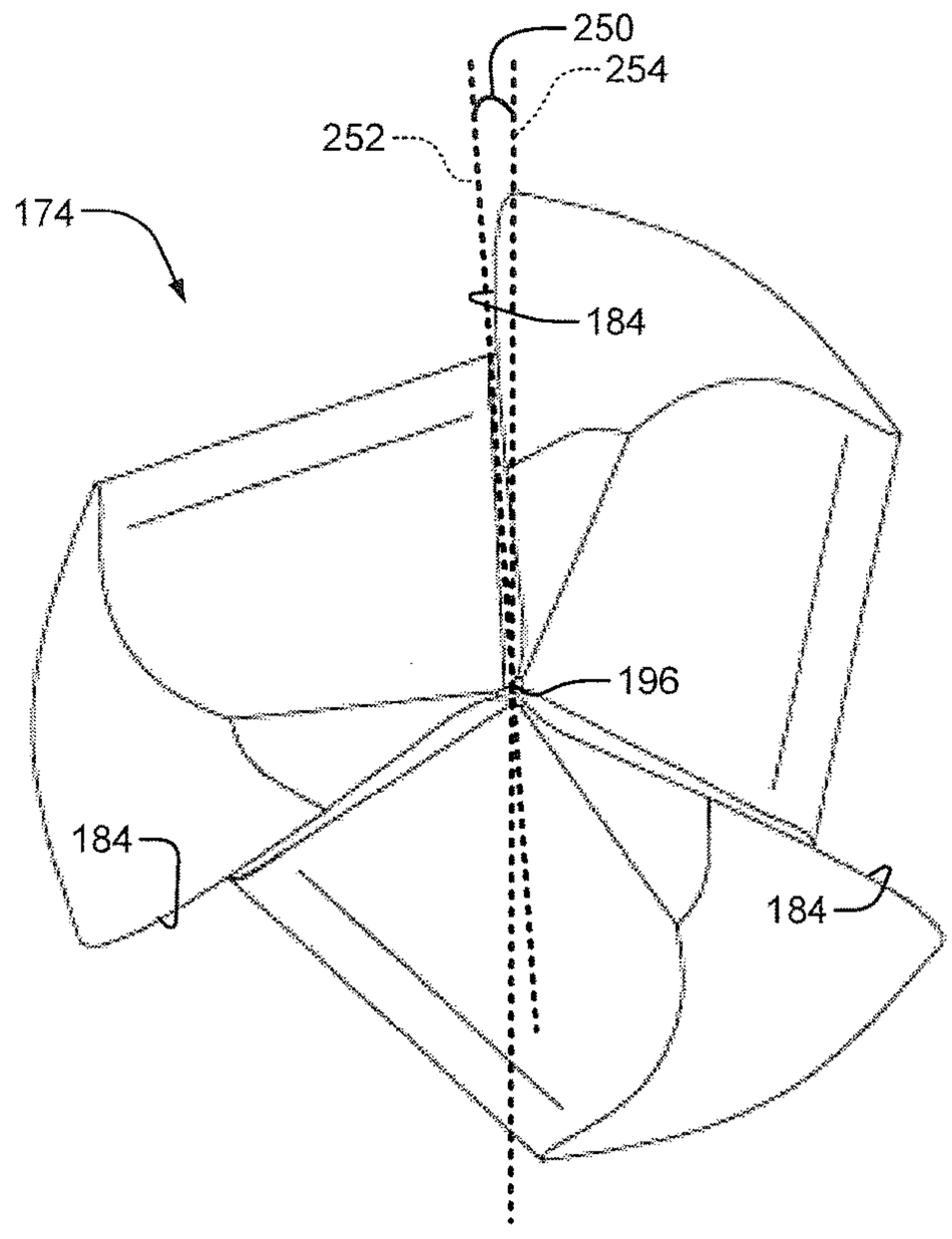

FIG. 11

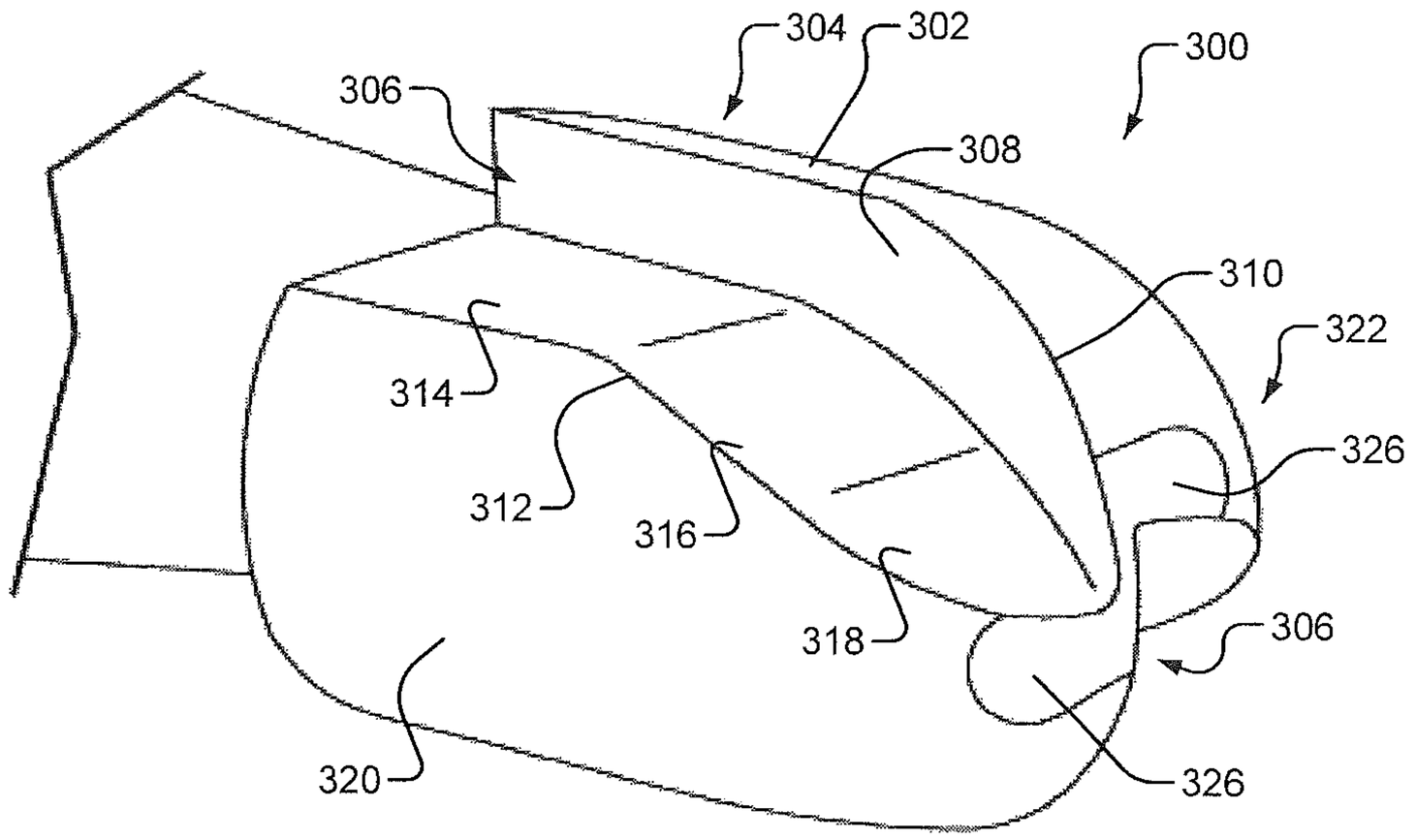
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FIG. 12

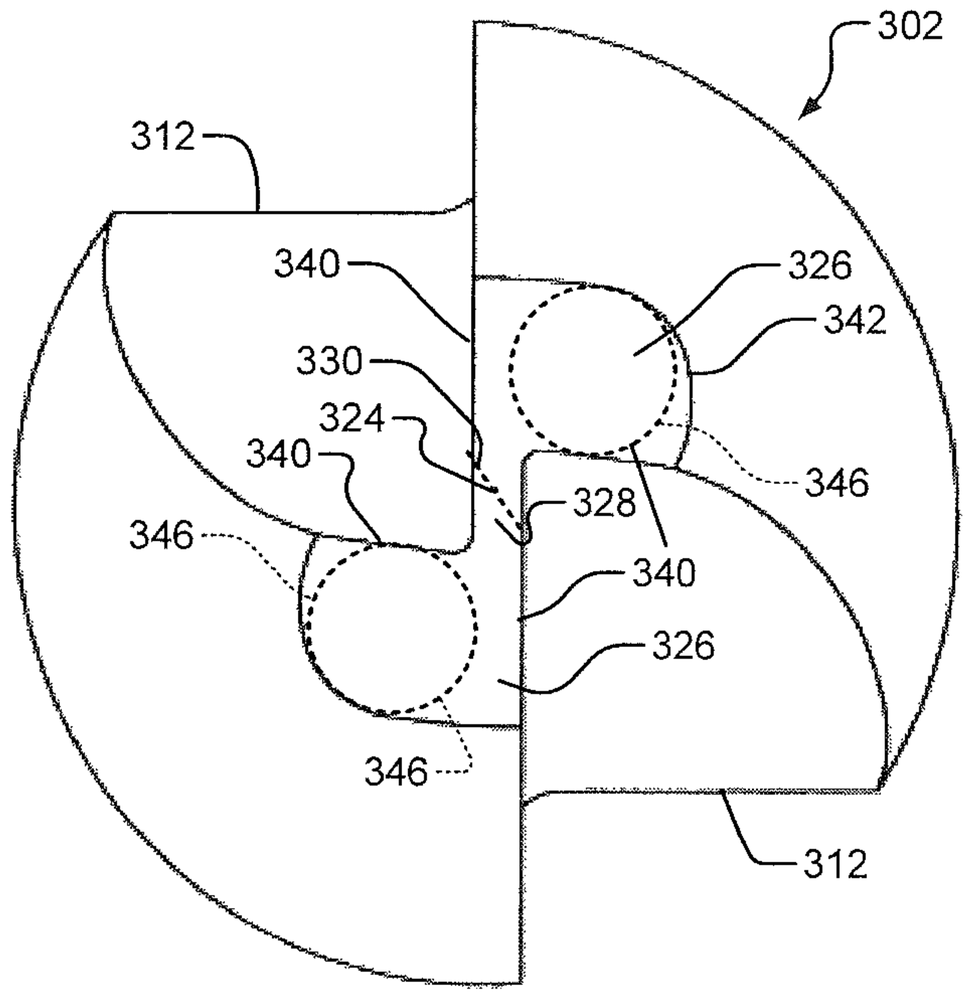
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FIG. 13

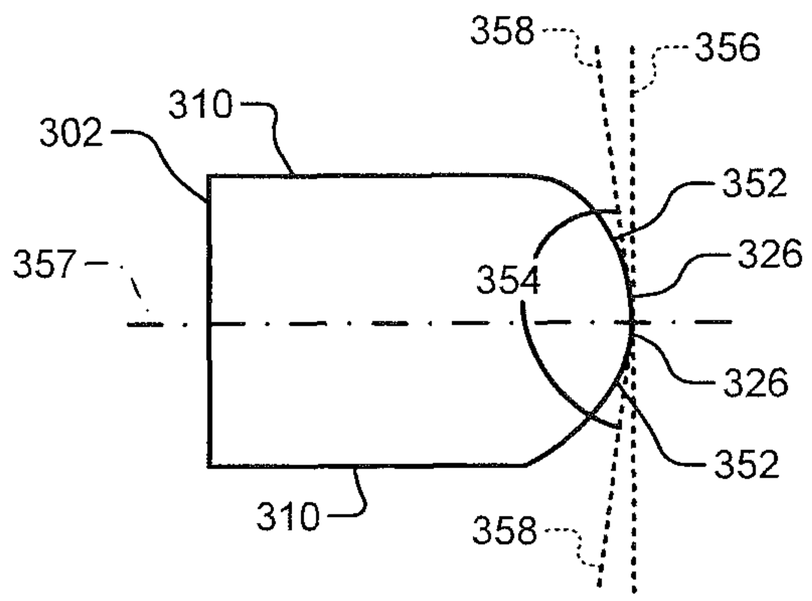


FIG. 14

SURGICAL BURS WITH GEOMETRIES HAVING NON-DRIFTING AND SOFT TISSUE PROTECTIVE CHARACTERISTICS

FIELD

The disclosure relates to a surgical systems for bone cutting or shaping, and more particularly to surgical burs.

BACKGROUND

This section provides background information related to the present disclosure which is not necessarily prior art.

Surgical burs need sharp and durable cutting edges in order to efficiently dissect, cut and/or shape bone during a surgical procedure. Human anatomy tends to locate sensitive soft tissue structures, such as nerves and blood vessels, near bones for protection. These structures can include the dura mater. Dura mater (or dura) refers to the outermost layer of protective soft tissue surrounding the brain and spinal column of a patient. During cranial and spinal procedures, the distal end of a bur can come in contact with dura mater. The term "distal" means furthest away from a medical practitioner holding a surgical tool with a rotating bur. The term "proximal" means towards the medical practitioner and away from the patient.

Damage to the dura mater can increase risks of infections (e.g., meningitis) and/or result in surgical complications (e.g., swelling of the brain). Thus, in order to preserve the integrity of the dura mater, it is desirable for surgical burs, intended for dissection of bone, to have a high-level of control (minimal flail or chatter) and have a geometry not predisposed to dissect soft tissue.

SUMMARY

This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

A surgical bur is provided and includes a body and a drill point. The body includes flutes and lands. Each of the flutes includes a cutting edge, a rake face, and a clearance surface. Each of the lands is convex-shaped and disposed between a pair of the flutes. The drill point includes axial relief surfaces. Each of the axial relief surfaces has a planar area, is distinct from the lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the lands, and (iii) one of the clearance surfaces.

In other features, a surgical bur is provided and includes a body and a drill point. The body includes flutes and lands. Each of the flutes includes a cutting edge and a clearance surface. Each of the lands is disposed between a pair of the flutes. The drill point includes axial relief surfaces. Each of the axial relief surfaces is distinct from the lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the lands, and (iii) one of the clearance surfaces. At least one axial relief angle of the axial relief surfaces is within a predetermined range.

In other features, a surgical bur is provided and includes a body and a drill point. The body includes flutes and lands. Each of the flutes includes a cutting edge and a clearance surface. Each of the lands is disposed between a pair of the flutes. The drill point includes axial relief surfaces. Each of the axial relief surfaces is distinct from the lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the lands, and (iii) one of the clearance surfaces. The drill point has a drill point angle of greater than or equal to a predetermined angle.

Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

FIG. **1** is a side perspective view of three drill bits illustrating drill point angles.

FIG. **2** is a side view of a dissection tool.

FIG. **3** is an end view of the dissection tool of FIG. **2**.

FIG. **4** is a perspective view of a surgical dissection cutter assembly incorporating a bur and in use on a patient in accordance with an embodiment of the present disclosure.

FIG. **5** is a perspective view of the surgical dissection cutter assembly of FIG. **4**.

FIG. **6** is a perspective view of a portion of a surgical bur illustrating a rake angle and a relief angle in accordance with an embodiment of the present disclosure.

FIG. **7** is a perspective view of a dissection tool including a surgical bur in accordance with an embodiment of the present disclosure.

FIG. **8** is a side view of the dissection tool of FIG. **7**.

FIG. **9** is a side view of the surgical bur of FIG. **7** orthogonal to the distal end portion of one of multiple cutting edges of the surgical bur.

FIG. **10** is another side view of the dissection tool of FIG. **7**.

FIG. **11** is a distal end view of the surgical bur of FIG. **7**.

FIG. **12** is a perspective view of another dissection tool having a surgical bur in accordance with another embodiment of the present disclosure.

FIG. **13** is a distal end view of the dissection tool of FIG. **12**.

FIG. **14** is a side view of the surgical bur of FIG. **12** illustrating a drill point angle.

Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

Drill bits for machining naturally occurring and/or engineered materials, such as metal, wood and plastic have drill point geometries for improved cutting efficiency, stability, and feed rates, as well as for minimized thermal energy build-up during machining. In general, drill point angles for machining softer materials are more acute than those for machining harder materials.

FIG. **1** shows side views of three drill bits **10**, **12**, **14** and corresponding drill point angles **16**, **18**, **20**. A drill point angle refers to an angle between tip cutting edges (e.g., tip cutting edges **22**, **24**) of a tip (e.g., tip **26**) of a drill bit. The tip cutting edges extend radially away from (i) a center (e.g., center **28**) of the tip, and (ii) respective ends of a chisel edge (e.g., chisel edge **30**) of the drill bit.

The drill bits **10**, **12**, **14** are shaped to work on materials having different hardness characteristics. The drill point angle **16** of the first drill bit **10** may be, for example, 118° and is for materials having a first hardness. The first drill bit

10 has the tip cutting edges 22, 24. The drill point angle 18 of the second drill bit 12 may be, for example, 135° and is for materials having a second hardness. The second hardness is greater than the first hardness. The second drill bit 12 has tip cutting edges 32, 34. The drill point angle 20 of the third drill bit 14 may be, for example, 90° and is for materials have a third hardness. The third hardness is less than the second hardness and the first hardness. The third drill bit 14 has tip cutting edges 36, 38.

The drill bits 10, 12, 14 have respective tips 26, 39, 40. Each of the tips 26, 39, 40 includes relief surfaces that extend away from the respective cutting edges 22, 24, 32, 34, 36, 38. Although the relief surfaces are distinct surfaces, the relief surfaces are identified by numerical designator 41. The relief surfaces 41 are convex-shaped.

Each of the drill bits 10, 12, 14 has two helically shaped lands and two flutes. Although the lands are distinct surfaces, the lands are identified by numerical designator 40. Although the flutes are distinct from each other, the flutes are identified by numerical designator 42. The lands 40 are not convex-shaped. Each of the flutes 42 is located between a pair of the lands 40 and has a corresponding chip space 43 along and in the flutes. The lands 40 are in respective 180° locations about a corresponding longitudinal axis (the longitudinal axes are identified by numerical designator 44). The flutes 42 are also in respective 180° locations about a corresponding longitudinal axis.

FIG. 2-3 show side and distal end views of a predicate dissection tool 50 including a surgical bur 52. The surgical bur 52 includes three cam shaped lands 54 and three flutes 56. Each of the flutes 56 is located between a pair of the lands 54 and has a corresponding chip space 57. The lands 54 are equally spaced about a longitudinal axis 58 of the surgical bur 52. The longitudinal axis 58 is shown by point 60 in FIG. 2. Distal portions 62 of the lands 54 are referred to as axial relief surfaces 63, which are convex-shaped. The axial relief surfaces 62 are not distinct from the lands 54 because: the lands 54 and the axial relief surfaces 62 are both convex-shaped (or have the same type of surface); and the axial relief surfaces 62 are continuous with the lands 54 without transitional surfaces or borders between the axial relief surfaces 62 and the lands 54.

The flutes 56 are also equally spaced about the longitudinal axis 58. Each of the flutes 56 has a rake face 64 with a cutting edge 66 and a clearance surface 68. Each of the clearance surfaces 68 includes distal portion (or surface) and a proximal portion (or surface). The distal portions of the clearance surfaces 68 are identified by numerical designator 70. The proximal portions of the clearance surfaces 68 are identified by numerical designator 72.

The geometries of the drill bits 10, 12, 14 of FIG. 1 and the surgical bur 52 of FIGS. 2-3 have associated disadvantages. Although the drill bits 10, 12, 14 provide cutting efficiency and stability due to the corresponding drill point angles, the geometries of the drill bits 10, 12, 14 would be inappropriate for surgical use in certain procedures. This is because the drill bits would likely cut dura mater and can be difficult to use for shaping purposes. The tips 26, 39, 40 of the drill bits 10, 12, 14 have a minimal amount of contact surface area, which increases chances of cutting dura mater. Although the surgical bur 52 is rounded and has a less tendency to cut dura mater than the drill bits 10, 12, 14, the surgical bur 52 has an increased tendency to drift due to the geometries of a distal end or tip 74 of the surgical bur 52. The surgical bur 52 also has a greater amount of contact area, requiring more irrigation to mitigate friction and the concomitant torsional shear forces that may be exerted on an underlying soft tissue structure. For at least these reasons, it is desirable to construct surgical burs (or drilling tools) with geometries including a rounded tip and certain rake, axial relief and drill point angles, such that the surgical burs do not engage soft tissue and/or dura mater.

The following description discloses rotatable surgical burs (referred to below as the surgical burs). The surgical burs have fewer tendencies to cut dura mater and increased tendency to cut bone more efficiently as compared to predicate burs due to the geometries of the surgical burs. The surgical burs also have fewer tendencies to drift into sensitive anatomy. The surgical burs have tips with distal geometries that allow the surgical burs, with adequate irrigation, to glide over the dura mater without engaging and/or tearing the dura mater. The distal geometries include: axial relief surfaces with planar shapes and increased surface area; drill point angles in predetermined ranges; and axial relief angles in predetermined ranges. The distal geometries are set for maximum cutting and stability performance and for minimal tendencies to engage dura mater. The gliding aspect occurs over dura mater as opposed to bone due to the soft flexible nature of dura mater and the balance of surface area, shapes, and angles of the axial relief surfaces. The surgical burs have an increased tendency to cut into bone where the surgical burs are placed without drifting into nearby anatomy.

Although the surgical burs disclosed herein may be used, for example, for cutting and shaping bone, the surgical burs may be used for other dissecting, cutting, and/or shaping purposes. The disclosed implementations include bur configurations that minimize risk for challenges to sensitive anatomy, in particular, dura mater. The surgical burs are constructed with geometry to allow a practitioner to perform a procedure (e.g., a craniotomy) including casual contact atop dura mater. The surgical burs allow the practitioner to create a bore through a bone and/or a lateral path in the bone without tearing dura mater.

Example embodiments will now be described more fully with reference to the accompanying drawings. The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.

FIG. 4 shows a surgical dissection cutter assembly 100 incorporating a rotating surgical bur in use on a patient 102. The patient is undergoing a neurological operation. Access to the brain or other neurological structures often requires delicate dissection of bone and other tissues. FIG. 4 is provided for example purposes only, the surgical burs disclosed herein may be used in different tools and/or cutter assemblies and may be used for other procedures and/or operations. The dissection cutter assembly 100 includes a dissection tool driver 104, which is being utilized to dissect a portion of bone and adjacent tissue of the patient 102 in the surgical access site 106.

FIG. 5 is a perspective view of the surgical dissection cutter assembly 100. The dissection tool driver 104 includes a motor housing 108 connected to a hose or cable assembly 110. The hose assembly 110 supplies external power and control for the motor housing 108. The dissection tool driver 104 further includes an attachment housing 112 that connects to a dissection tool 118. A distal end of the dissection tool 118 includes a surgical bur 120. Examples of the dissection tool 118 are shown and described below with reference to FIGS. 6-13.

FIG. 6 is a perspective view of a portion 130 of a surgical bur. The portion 130 includes a rake face 132 with a cutting

edge **134** and a relief surface **136**. The cutting edge **134** may be at a distal end of the surgical bur and adjacent to the axial relief surface **136**. A rake angle **138** of the rake face **132** may be between (i) a line (or plane) **140** on the rake face **132** and a plane perpendicular to the cutting edge **134** and (ii) a line (or plane) **142** extending perpendicular to a surface **144** of a bone **145** into which the surgical bur is cutting and extending in a direction of the cut and/or a line (or plane) **146** perpendicular to line **142**. An axial relief angle **148** may be between (i) a line (or plane) **150** on the axial relief surface **136** and a plane perpendicular to the cutting edge **134** and (ii) the line **146**.

Although the following surgical burs are shown as having a particular number of flutes, lands, axial relief surfaces, clearance surfaces, etc., the surgical burs may have other quantities of each of these items.

FIG. **7** is a perspective view of a dissection tool **170**. The dissection tool **170** includes a shaft **172** and a surgical bur **174**. The surgical bur **174** includes a body **176**. The body **176** has three cam shaped lands **178** and three flutes **180**. Each of the flutes **180** is located between a pair of the lands **178** and has a corresponding chip space **181**. The lands **178** are convex-shaped and/or rounded and may be in respective 120° locations about a longitudinal axis **182** of the dissection tool **170**, the shaft **172**, and/or the surgical bur **174**. The flutes **180** may also be in respective 120° locations about the longitudinal axis **182**. Each of the flutes **180** has a rake face **184** with a cutting edge **186** and a clearance surface **188**. Each of the clearance surfaces **188** includes a distal portion (or surface) **190** and a proximal portion (or surface) **192**.

The surgical bur **174** includes a drill point **194** at a distal end of the surgical bur **174**. The drill point **194** may include a center point **196** and three axial relief surfaces **198**. The longitudinal axis **182** passes through the center point **196**. The axial relief surfaces **198** are at ends of the flutes **180** and are distinct from the lands **178**. The axial relief surfaces **198** are distinct from the lands **178** because: the axial relief surfaces **198** are a different type of surface than the lands (e.g., the lands **178** may be convex-shaped and the axial relief surfaces **198** may be planar shaped); there are transitional surfaces (or borders) between the axial relief surfaces **198** and the lands **178**; and/or the axial relief surfaces **198** do provide a non-transitional (or continuous surface) with the lands.

Each of the axial relief surfaces **198** are bordered by (i) a respective distal end portion **200** of one of the cutting edges **186**, (ii) a distal end portion **202** of one of the lands **178**, and (iii) one of the distal portions **190** of one of the clearance surfaces **188**. The axial relief surfaces **198** may be flat (or planar) surfaces, as shown. Each of the axial relief surfaces **198** are triangular-shaped with two nominally straight edges (two of the nominally straight edges are identified by numerical designator **204**) and a curved edge (one of the curved edges is identified by numerical designator **206**). The curved edges **206** of the axial relief surfaces **198** border respectively the lands **178**.

FIG. **8** shows another side view of the dissection tool **170** including the surgical bur **174** is shown. The surgical bur **174** includes the cutting edges **186**. The cutting edges **186** may provide a right-hand helix, straight or left-hand helix with respect to the longitudinal axis **182**. The cutting edges **186** are shown as providing a right-hand helix. When viewed from the side and as shown, the cutting edges **186** of the right-hand helix configuration extend along the longitudinal axis **182**, generally from above to below the, and towards the drill point **194**. When viewed from the side, the cutting edges **186** of the straight configuration extend towards the drill point **194** and parallel with the longitudinal axis **182**. When viewed from the side, the cutting edges **186** of the left-hand helix configuration extend along the longitudinal axis **182**, generally from below to above, and towards the drill point **194**.

The surgical bur **174** also includes the clearance surfaces **188** having the distal surfaces **190**. The distal surfaces **190** have corresponding gash angles (one gash angle **210** is shown). Each of the gash angles refers to an angle between (i) a line (or plane) **212** extending parallel to one of the distal surfaces **190** and away from the center point **196** and/or the longitudinal axis **182** and (ii) a line (or plane) **214** extending perpendicular to the longitudinal axis **182**.

FIG. **9** shows another side view of the surgical bur **174** orthogonal to the distal end portion **200** of one of the cutting edges **186**. The surgical bur **174** includes the axial relief surfaces **198** (one is shown in FIG. **9**) and the rake faces **184** (one is shown in FIG. **9**) with corresponding cutting edges **186** therebetween.

Each of the axial relief surfaces **198** has a corresponding axial relief angle (one axial relief angle **220** is shown) and axial rake angle (one axial rake angle **221** is shown). Each axial relief angle **220** can be measured between (i) a first line (or plane) **224** on an axial relief surface and observed perpendicular to the distal end portion **200** of one of the cutting edges **186** and (ii) a second line (or plane) **226** perpendicular to the longitudinal axis **182**. The second plane **226** may also extend across a surface of an object (e.g., a surface of a bone) being cut. Each axial rake angle refers to an angle between (i) a third line (or plane) **230** on one of the rake faces **184** and observed perpendicular to the distal end portion **200** of one of the cutting edges **186** and (ii) a fourth line (or plane) extending along, passing through, and/or parallel to the longitudinal axis **182**.

Each distal portion **222** of the cutting edges **186**, along a corresponding one of the axial relief surfaces **198**, has a corresponding axial relief surface angle, a drill point angle, and a remainder angle. The axial relief surface angle (e.g., axial relief surface angle **220**) refers to an angle between (i) a line (or plane) **224** extending along and parallel to one of the axial relief surfaces **198** and away from the longitudinal axis **182** and/or distal portion **222** of one of the cutting edges **186**, and (ii) a line (or plane) **226** extending perpendicular to the longitudinal axis **182** and passing through the center point **196**.

A remainder angle (e.g., remainder angle **218**) may refer to an angle between (i) a line (or plane) **230** on one of the rake faces **184** and observed perpendicular to the distal end portion **200** of one of the cutting edges **186** and (ii) the line (or plane) **224** extending along and parallel to one of the axial relief surfaces **198** and away from the longitudinal axis **182** and/or the distal portion **222** of one of the cutting edges **186**. The remainder angle **218** is shown in FIGS. **7** and **9**. The remainder angle **218** may be an acute, right, or obtuse angle. In one implementation, the remainder angle **218** is an obtuse angle.

A drill point angle is described with respect to FIG. **10** and an example drill point angle is shown in FIG. **14**. FIG. **10** shows a side view of the dissection tool **170** including the surgical bur **174** is shown. Multiple techniques may be used to determine the drill point angle. A drill point angle DP (not shown in FIG. **9**) may be equal to 180° minus two times an acute angle (AA) (or DP=180°−2AA). The acute angle AA refers to an angle between (i) a line (or plane) **240** extending perpendicular to the longitudinal axis and tangent to the center point **196** and (ii) a line (or plane) **242** extending parallel to the distal portion **222** of one of the cutting edges

186. When a surgical bur has two flutes and/or opposing cutting edges with distal portions 180° apart and extending away from a center point, a corresponding drill point angle of the surgical bur refers to an angle between distal portions of the cutting edges. An example surgical bur with two flutes is shown in FIGS. **12-13**.

FIG. **11** shows a distal end view of the surgical bur **174**. The surgical bur **174** includes the rake faces **184**. Each of the rake faces **184** has a corresponding radial rake angle **250**. A radial rake angle **250** refers to an angle between (i) a line (or plane) **252** parallel to a rake face and (ii) a line (or plane) **254** passing through the cutting edge **186** and the longitudinal axis. Radial rake angles **250** of the rake faces **184** may be associated with a left-hand helix, straight or righted-hand helix with respect to the longitudinal axis **182** (shown in previous FIGS. **7-9**). The rake faces **184** of the surgical bur **174** as shown provide a right-hand helix.

FIGS. **12** and **13** show perspective and distal end views of another dissection tool **300** having a surgical bur **302**. The surgical bur **302** as shown has a straight configuration. The surgical bur **302** has a body **304** with two flutes **306** equally spaced around longitudinal axis **357**.

Each of the flutes **306** has a rake face **308** with a cutting edge **310** and a clearance surface **312**. Each clearance surface **312** may include a proximal portion (or surface) **314**, a center portion (or surface) **316**, and a distal portion (or surface) **318**. A land **320** exists between each cutting edge **310** and a corresponding clearance surface **312**. The lands **320** are convex-shaped.

The surgical bur **302** also includes a drill point **322** with a center point **324** and axial relief surfaces **326**. The axial relief surfaces **326** may be flat (or planar) surfaces. A bridge **328** may extend between the axial relief surfaces **326** and/or be part of the axial relief surfaces **326**. The bridge **328** may extend across the center point **324** and have a corresponding thickness and/or a chisel edge **330**. In one implementation, the bridge **328** does not include a chisel edge. The chisel edge **330** may extend across the bridge **328** between the flutes **306**. Each of the axial relief surfaces **326** includes two straight edges **340** and a curved edge **342**. The curved edges **342** border respectively the lands **320**. Each of the axial relief surfaces **326** may include circular areas **346**. In one implementation, the circular areas **346** are flat (or planar), protrude from the remainder of the axial relief surfaces **326**, and do not protrude from (or in a more distal direction than) the bridge **328**. In another implementation, the axial relief surfaces **326** do not include the circular areas **346**.

The rake faces **308**: extend parallel to each other; are not in alignment with each other; are offset from each other; and have overlapping portions (i.e. the portions are side-by-side) at the bridge **328**. Similarly, the straight edges **340**: extend parallel to each other; are not in alignment with each other; are offset from each other; and have overlapping portions (i.e. the portions are side-by-side) at the bridge **328**.

FIG. **14** shows a side view of the surgical bur **302**. The surgical bur **302** includes the cutting edges **310** and axial relief surfaces **326**. The distal portions **352** of the cutting edges **310** have an associated drill point angle **354**. The drill point angle **354** is an obtuse angle. Acute angles between (i) distal portions **352** and (ii) a line (or plane) **356**. A sum of the drill point angle **354** and the acute angles **356**, **358** is equal to 180°. The plane **356** is perpendicular to a longitudinal axis **357** of the surgical bur **302**. Lines (or planes) **358** tangent to the axial relief surfaces **326** are shown.

The above-disclosed implementations include surgical bur configurations designed to cut and shape bone efficiently while allowing contact with sensitive soft tissue structures (e.g., nerves, blood vessels, membranes, etc.) without tearing the soft tissue structures. This is especially applicable in neurological and spinal procedures where the dura mater can be exposed to a distal portion of a bur.

In certain implementations, drill point angles of surgical burs (e.g., the surgical burs **174** and **302**) are obtuse angles greater than or equal to a first predetermined angle (e.g., 140°) and/or are within a first predetermined range (e.g., between 140°-160°). Corresponding axial relief angles of the surgical burs are less than or equal to a second predetermined angle (e.g., 25°) and/or are within a second predetermined range (e.g., between 5°-25°. An example drill point angle is shown in FIG. **14**. An example axial relief angles are shown in FIGS. **6** and **9**. These drill point angles and axial relief angles provide stable cutting of hard surfaces (such as surfaces of bone) while allowing the surgical burs to glide over soft surfaces (e.g., surfaces of dura mater). This is further improved by having the axial relief surfaces be planar surfaces. Rake angles of the surgical burs may also be within predetermined ranges and based on the application of use.

As a result, "skating" over hard surfaces is prevented providing improved and consistent drilling control while not challenging (or negatively affecting) integrity of dura mater. Reduced skating improves cutting quality while reducing risk of surgical complications concomitant with dural tears. The geometry of the surgical burs including the drill point angles and axial relief angles are tunable (i.e. can be adjusted) based on the application of use.

Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise.

The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

What is claimed is:

1. A surgical bur comprising:

a body that is spherically-shaped, wherein the body comprises

a plurality of flutes, wherein each of the plurality of flutes comprises a cutting edge, a rake face and a clearance surface, and

a plurality of lands, each of the plurality of lands is convex-shaped and disposed between a pair of the plurality of flutes; and

a drill point comprising a plurality of axial relief surfaces, wherein each of the plurality of axial relief surfaces has a planar area, is distinct from the plurality of lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the plurality of lands, and (iii) one of the clearance surfaces;

wherein widths of the plurality of axial relief surfaces narrow towards a distal end of the drill point; and

wherein lengths of proximal most edges of the plurality of axial relief surfaces are equal to lengths of distal most edges of the plurality of lands.

2. The surgical bur of claim **1**, wherein drill point angles of distal portions of the cutting edges are each between 140°-160°.

3. The surgical bur of claim **1**, wherein axial relief angles of the plurality of axial relief surfaces are each between 5°-25°.

4. The surgical bur of claim **1**, wherein the plurality of axial relief surfaces are planar surfaces and meet at a center point.

5. The surgical bur of claim **4**, wherein:

entire areas of the plurality of axial relief surfaces are respectively between the plurality of lands and the center point; and

the plurality of axial relief surfaces separate the plurality of lands from the center point.

6. The surgical bur of claim **1**, wherein:

drill point angles of distal portions of the cutting edges are each between 140°-160°; and

axial relief angles of the plurality of axial relief surfaces are each between 5°-25°.

7. The surgical bur of claim **1**, wherein:

the plurality of axial relief surfaces are triangular-shaped and comprise two straight edges and a curved edge; and

each of the curved edges of the plurality of axial relief surfaces border a respective one of the plurality of lands.

8. The surgical bur of claim **1**, wherein the planar areas are circular in shape.

9. The surgical bur of claim **1**, wherein:

at least one axial relief angle of the plurality of axial relief surfaces is less than or equal to a predetermined angle such that the surgical bur while rotating has a tendency to cut a first type of surface and not a second type of surface;

the first type of surface has a first hardness; and

the second type of surface has a second hardness that is less than the first hardness.

10. The surgical bur of claim **1**, wherein:

the plurality of flutes are non-opposing flutes; and

the plurality of axial relief surfaces are connected via a bridge.

11. The surgical bur of claim **1**, wherein each of the plurality of lands is convex-shaped along a longitudinal center axis of the surgical bur and from a proximal end of the body to a corresponding one of the plurality of axial relief surfaces.

12. The surgical bur of claim **11**, wherein each of the plurality of lands is convex-shaped in a lateral direction between adjacent ones of the plurality of flutes.

13. The surgical bur of claim **1**, wherein each of the cutting edges extend along a longitudinal center axis of the surgical bur from a proximal end of the surgical bur to a distal end of the surgical bur.

14. The surgical bur of claim **1**, wherein each of the cutting edges, in a distal portion of the surgical bur, abuts a respective one of the plurality of lands and a respective one of the plurality of axial relief surfaces.

15. The surgical bur of claim **1**, wherein:

the plurality of axial relief surfaces are planar surfaces, meet at a center point at a distal end of the surgical bur, and are triangular-shaped;

each of the plurality of axial relief surfaces has three edges;

the first edges border respectively the plurality of lands;

the second edges border respectively the clearance surfaces; and

the third edges border respectively the cutting edges.

16. The surgical bur of claim **15**, wherein:

each of the second edges of the plurality of axial relief surfaces extends along a respective one of the clearance surfaces; and

points of the plurality of axial relief surfaces between the second edges and the third edges meet at the center point.

17. The surgical bur of claim **1**, wherein a proximal end of each of the plurality of axial relief surfaces that borders a respective one of the plurality of lands is at an acute remainder angle relative to a respective one of the cutting edges bordering the respective one of the plurality of lands.

18. The surgical bur of claim **1**, wherein:

each of the plurality of axial relief surfaces is a single surface having a respective peripheral boundary;

each of the plurality of axial relief surfaces are void of a transitional edge within the corresponding peripheral boundary; and

a transitional edge refers to an edge between two distinct surfaces.

19. The surgical bur of claim **1**, wherein:

each of the plurality of axial relief surfaces comprises three edges;

the cutting edges extend along the first edges of the plurality of axial relief surfaces;

the plurality of lands have distal edges that extend along the second edges of the plurality of axial relief surfaces; and

the clearance surfaces have distal edges that extend along the third edges of the plurality of axial relief surfaces.

20. The surgical bur of claim **1**, wherein the rake faces are offset from each other, are not in alignment with each other; and have overlapping portions.

21. The surgical bur of claim **20**, wherein:

the rake faces extend parallel to each other; and

the overlapping portions are side-by-side to provide a bridge between the planar areas.

22. The surgical bur of claim **1**, wherein each of the plurality of axial relief surfaces is planar-shaped.

23. The surgical bur of claim **1**, wherein each of the plurality of axial relief surfaces is distal to a respective one of the clearance surfaces.

24. The surgical bur of claim **1**, wherein each of the plurality of axial relief surfaces is distal to a respective one of the plurality of lands.

25. The surgical bur of claim **1**, wherein the plurality of axial relief surfaces, the clearance surfaces and the cutting edges meet at a distal center end point of the surgical bur.

26. A surgical bur comprising:

a body that is spherically-shaped, wherein the body comprises

a plurality of flutes, wherein each of the plurality of flutes comprises a cutting edge, a rake face, and a clearance surface, and

a plurality of lands, each of the plurality of lands is disposed between a pair of the plurality of flutes; and

a drill point comprising a plurality of axial relief surfaces, wherein each of the plurality of axial relief surfaces is distinct from the plurality of lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the plurality of lands, and (iii) one of the clearance surfaces, wherein a proximal most edge of each of the plurality of axial relief surfaces borders a distal most edge of a respective one of the plurality of lands;

wherein widths of the plurality of axial relief surfaces narrow towards a distal end of the drill point; and

wherein lengths of the proximal most edges of the plurality of axial relief surfaces are equal to lengths of the distal most edges of the plurality of lands.

27. The surgical bur of claim **26**, wherein:

each of the plurality of lands is convex-shaped; and

the plurality of axial relief surfaces are planar surfaces.

28. The surgical bur of claim **26**, wherein:

at least one axial relief angle of the plurality of axial relief surfaces is less than or equal to a predetermined angle such that the surgical bur while rotating has a tendency to cut a first type of surface and not a second type of surface;

the first type of surface has a first hardness; and

the second type of surface has a second hardness that is less than the first hardness.

29. The surgical bur of claim **26**, wherein axial relief angles of the plurality of axial relief surfaces are each less than or equal to 25°.

30. The surgical bur of claim **26**, wherein axial relief angles of the plurality of axial relief surfaces are each between 5°-25°.

31. The surgical bur of claim **26**, wherein drill point angles of distal portions of the cutting edges are each between 140°-160°.

32. The surgical bur of claim **26**, wherein the plurality of axial relief surfaces are planar surfaces.

33. The surgical bur of claim **26**, wherein each axial relief surface of the surgical bur is distal to a respective one of the plurality of lands or a respective one of the clearance surfaces.

34. The surgical bur of claim **26**, wherein each axial relief surface of the surgical bur is distal to a respective one of the plurality of lands and a respective one of the clearance surfaces.

35. The surgical bur of claim **26**, wherein each of the proximal most edges of the axial relief surfaces extends laterally between a respective one of the clearance surfaces and a respective one of the rake faces.

36. A surgical bur comprising:

a body that is spherically-shaped, wherein the body comprises

a plurality of flutes, wherein each of the plurality of flutes comprises a cutting edge and a clearance surface, and

a plurality of lands, each of the plurality of lands is disposed between a pair of the plurality of flutes, wherein each of the cutting edges borders a respective one of the plurality of lands in a distal portion of the surgical bur; and

a drill point comprising a plurality of axial relief surfaces, wherein each of the plurality of axial relief surfaces is distinct from the plurality of lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the plurality of lands, and (iii) one of the clearance surfaces, wherein the drill point has a drill point angle of greater than or equal to a predetermined angle, and wherein a proximal end of each of the plurality of axial relief surfaces that borders a respective one of the plurality of lands is at an acute remainder angle relative to a respective one of the cutting edges bordering the respective one of the plurality of lands.

37. The surgical bur of claim **36**, wherein:

the drill point angle is within a predetermined range such that the surgical bur while rotating has a tendency to cut a first type of surface and not a second type of surface;

the first type of surface has a first hardness; and

the second type of surface has a second hardness that is less than the first hardness.

38. The surgical bur of claim **37**, wherein drill point angles of distal portions of the cutting edges are each between 140°-160°.

39. The surgical bur of claim **36**, wherein axial relief angles of the plurality of axial relief surfaces are each between 5°-25°.

40. The surgical bur of claim **36**, wherein the plurality of axial relief surfaces are planar surfaces.

41. A surgical bur comprising:

a body comprising

a plurality of flutes, wherein each of the plurality of flutes comprises a cutting edge, a rake face and a clearance surface, and

a plurality of lands, wherein each of the plurality of lands is convex-shaped and disposed between a pair of the plurality of flutes; and

a drill point comprising a plurality of axial relief surfaces, wherein each of the plurality of axial relief surfaces has a planar area, is distinct from the plurality of lands and borders (i) a distal portion of one of the cutting edges, (ii) one of the plurality of lands, and (iii) one of the clearance surfaces,

wherein each of the plurality of lands comprises

a first portion convex-shaped in a lateral direction between the plurality of flutes and is not convex-shaped along a longitudinal axis of the surgical bur, and

a second portion convex-shaped in a lateral direction between the plurality of flutes and convex-shaped along the longitudinal axis of the surgical bur;

wherein a proximal end of each of the plurality of axial relief surfaces that borders a respective one of the plurality of lands is at an acute remainder angle relative to a respective one of the cutting edges bordering the respective one of the plurality of lands.

42. The surgical bur of claim **41**, wherein each axial relief surface of the surgical bur is distal to a respective one of the plurality of lands or a respective one of the clearance surfaces.

43. The surgical bur of claim **41**, wherein each axial relief surface of the surgical bur is distal to a respective one of the plurality of lands and a respective one of the clearance surfaces.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,883,873 B2
APPLICATION NO. : 13/944650
DATED : February 6, 2018
INVENTOR(S) : Kulas et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page

Page 2, Applicant Information: Delete "Louisville, CO" and insert --Fort Worth, TX-- therefore;

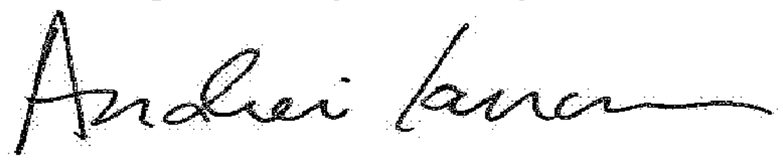
In the Specification

Column 3, Detailed Description, Line 28: Delete "FIG." and insert --FIGS.-- therefore;

Column 3, Detailed Description, Line 36: Delete "63," and insert --62,-- therefore; and

Column 8, Detailed Description, Line 12: Delete "5°-25°." and insert --5°-25°).-- therefore.

Signed and Sealed this
Eighth Day of May, 2018



Andrei Iancu
Director of the United States Patent and Trademark Office